Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

U.S. DEPARTMENT OF AGRICULTURE
CURRENT SERIAL RECORD
MAY 5 - 1950
LIBRARY

84C
5

Circular No. 818

October 1949 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Use of the Parasite Trichogramma Minutum for Controlling Pecan Insects

HERBERT SPENCER, LUTHER BROWN,[1] and ARTHUR M. PHILLIPS, *entomologists, Division of Fruit Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*[2]

CONTENTS

INTRODUCTION

In October 1930 a laboratory was established in Albany, Ga., to investigate the possibility of using beneficial insects for control of insect enemies of the pecan. Facilities were provided for study of the native parasites of insects attacking the pecan. Special apparatus was provided for mass propagation of a small wasp, *Trichogramma*

[1] Resigned January 31, 1934.

[2] The authors are grateful for the cooperation rendered by pecan growers and shippers, especially those who made their groves available for these experiments. Among technical workers, G. F. Moznette contributed much information from his wide experience with pecan insects and helped in getting this work under way; H. S. Adair gave information on the pecan shuckworm; K. W. Babcock and F. M. Wadley assisted in the arrangement of the experimental plots and final analysis of results; and H. L. Crane, J. B. Demaree, and John Large contributed information on horticultural and plant pathological matters. In the experiments in northern Florida G. H. Blackmon and the late F. W. Walker, of the Florida Agricultural Experiment Station, were very helpful.

minutum Riley. Throughout 5 seasons large numbers of these wasps were released in 19 groves for experiments on control of the pecan nut casebearer (*Acrobasis caryae* Grote), and in 6 groves each for the pecan leaf casebearer (*A. juglandis* (LeB.)) and the hickory shuckworm (*Laspeyresia caryana* (Fitch)). The results of these experiments are reported and discussed in this paper.

MASS PRODUCTION OF *Trichogramma*

The technique employed for rearing *Trichogramma* followed closely that developed by Flanders (*1*) [3] in California. At first production devices were modifications of those set up in Louisiana by Hinds and Spencer (*4*) for similar experiments on sugarcane insects. In the course of the work at Albany several improved rearing units were designed and built (*6*). These units increased vastly the output of parasites and made mass production more flexible, more responsive to sudden demands, and less subject to changes in weather and to undesirable biological influences.

The *Trichogramma* parasites were reared in petri dishes in eggs of the Angoumois grain moth (*Sitotroga cerealella* (Oliv.)). The grain moths were reared in shelled corn or wheat kernels kept in hanging frames of screen wire in boxlike rearing units. High temperatures and humidities in the production rooms favored rapid development of the moths. On emerging they were collected in traps on the rearing boxes and were transferred later to battery jars for egg laying. The eggs were cleaned by screening and were affixed to circular pieces of cardboard that would just fit into the petri dishes containing the parasites.

STRAINS AND SOURCES OF PARASITES

The mass breeding of *Trichogramma minutum* was begun late in the winter, when adults were practically unobtainable out-of-doors. A yellow variety of *Trichogramma* bred from eggs of *Acrobasis caryae* was sent by mail from the Brownwood, Tex., laboratory of the Bureau of Entomology and Plant Quarantine. For convenience it was designated the T strain. Other breeding strains obtained locally or from other experimenters also were assigned letters for identification, usually the initial of the locality of origin.

Almost all these strains were used in the grove experiments in the 5 years, but the apparently identical L and Z dark lines and the yellow strains A, C, and W were liberated in enormous numbers. *Trichogramma euproctidis* Gir. from Europe and a shiny black species reared from eggs of *Calpodes ethlius* (Stoll) would not increase in eggs of the Angoumois grain moth. Since both species were quite different from specimens bred from pecan insects, they were seldom used. Table 1 summarizes information on sources of the *Trichogramma* breeding stocks, the designations used in this work, and the general color characteristics of these strains.

[3] Italic numbers in parentheses refer to Literature Cited, p. 17.

TABLE 1.—*Strains of Trichogramma minutum used in experiments on control of insects attacking pecans*

Date and strain designation	Previous host	Source of parasite	Color of adults	Remarks
1931:				
T	*Acrobasis caryae*	Brownwood, Tex	Yellow	
A	*Laspeyresia caryana*	Albany, Ga	do	
1932:				
X	Climbing cutworm on pecan	do	do	
L	*Diatraea saccharalis* (F.)	Baton Rouge, La	Gray	Males more yellowish at high temperatures.
Z	*Colias philodice eurytheme* (*Bdvl.*)	Casa Grande, Ariz	do	Like L; probably identical.
F	*Calpodes ethlius* (Stoll)	Sanford, Fla	Black	
1933:				
C	*Carpocapsa pomonella* (L.)	Cornelia, Ga	Yellow	Like A.
W	do	Wenatchee, Wash	do	Indistinguishable from C.
1934:				
Y	*Grapholitha molesta* (Busck)	New Haven, Conn	do	Like C, females golden yellow.
B	do	do	Gray	Like L.

METHODS OF RELEASING PARASITES

Trichogramma minutum is one of the smallest and most delicate of the insect parasites. In the open, the adults can withstand light rains and winds by clinging to the under surfaces of leaves and objects in

Figure 1.—Cardboard segment bearing eggs parasitized by *Trichogramma minutum*, hung in pecan tree with fine wire, for emergence and releasement of the parasites.

Figure 2.—Paraffined release package containing eggs parasitized by *Trichogramma minutum.*

protected locations, but they cannot survive driving rains. For this reason releases were always made in mild weather. In the earlier of these experiments, parasitized grain moth eggs on cardboard were hung in pecan trees by fine copper wire (fig. 1) so that the parasites could complete their development and emerge outdoors. This method

was not satisfactory, however, because rains washed away some of the eggs containing the pupae, and ladybeetles and ants ate some. Later, small release packages (fig. 2) of paraffined paper were made to hold the card segments. In this way the parasites were protected against weather and enemies long enough for them to emerge, dry their wings and bodies, mate, and leave through small openings cut in the packages.

The method finally adopted as standard was to allow completion of development and emergence of adults in the laboratory in the petri dishes. Since a square centimeter of card held on the average about 1,000 parasitized eggs in which stages of *Trichogramma minutum* were developing, the numbers for the releases were regulated by placing larger or smaller segments of rearing cards in separate petri dishes before emergence of the adults. The mated adult parasites were liberated in the pecan trees simply by opening the dishes.

ARRANGEMENT OF EXPERIMENTAL PLOTS

Plans for the field experiments called for the use of paired plots, each plot to contain a sufficient number of trees to minimize the influence of tree variability, and the two plots of each pair to be as nearly alike as possible. In one plot of each pair the *Trichogramma* parasites were to be released, and the other plot was to be left uncolonized for comparison.

The more recent experimental designs, such as the randomized-block arrangement of plots or the Latin square, could not be used because the adult parasites that were released could easily fly from tree to tree, and there was no sure way of keeping these parasites confined in small plots. The parasites were released in 1 block of about 20 trees and a similar block several tree-rows away was used for a check so that the parasites would be unlikely to confuse results by flying into check trees.

THE PECAN NUT CASEBEARER

Seasonal History and Habits

The adult of the pecan nut casebearer is a small moth closely related to the codling moth (*Carpocapsa pomonella*) and the oriental fruit moth (*Grapholitha molesta*). Larvae of all three species bore into fruits in a similar manner. Those of the nut casebearer, on hatching, tunnel into the small pecans on which the eggs were laid. When food runs short, they go to the next nut of the cluster, leaving behind a silk-lined, frass-bedecked tunnel. The injured pecans drop to the ground although often some of the nuts hang on for a time, supported by the webbing. Sometimes 30 or 40 percent of the clusters may be infested and commercial losses may result from this drop. More often though one or two pecans of each infested cluster escape attack, particularly if tree growth is rapid at the time and the larvae obtain enough food to complete their development before all the nutlets have been consumed.

Seldom are two larvae found in one pecan cluster, because the eggs are laid singly and are well scattered by the female moths. Usually the egg is laid in a depression at the calyx end of the small pecan, but

sometimes it is placed near the stem end. Eggs are a transparent green, are flattened oval, and resemble the rough skins of the nut so closely that they are difficult to find. The spring brood oviposits over a 15-day period, beginning between May 10 and 25, the date varying from year to year with different weather conditions. There are other broods later in each season, but by that time natural enemies have reduced the numbers of the nut casebearers, and the nuts are so large that the slight infestation is seldom noticed.

It was evident from these habits and this seasonal history that to be effective at all, releases of *Trichogramma* parasites had to be made during the 15-day egg-laying period in the spring, beginning just as soon as the first signs of infestation could be found. Therefore each year the search for nut casebearer eggs began on May 7 and was continued daily until the first egg was found or until the first infested cluster was seen. The shortness of the spring egg-laying period was recognized as a major disadvantage in obtaining control with *Trichogramma minutum*, since there was almost no possibility of build-up of the parasites on host eggs after liberation. Accordingly, several releases of large numbers of parasites per tree were planned during those few days.

Selection of Groves for Experimental Control

Pecan groves with a heavy infestation seemed most desirable for these experiments because, from the practical standpoint, it was control of heavy outbreaks that was sought, and because larger host populations offered greater chances of showing differences.

The method of grove selection used in 1932 involved consideration of several requirements that seemed to be essential: (1) The trees had to have a crop of young nuts in the current season, because otherwise a grove could not possibly have nut casebearers in numbers; (2) the grove must have had at least a moderate crop for the preceding year or years, as otherwise presence of the pest in the grove in any considerable numbers was unlikely; (3) a definite history of regular heavy infestations made current infestation more probable, especially if the infestation was on the increase during the years covered by the observations. These essentials ruled out pecan varieties that are inclined to bear in alternate years, such as Schley, Stuart, and Pabst, and limited choice to regular croppers, such as Moore, Moneymaker, and Teche.

As the work progressed, more and more of the experiments were located near Monticello, Fla., where crops of nuts were produced more regularly, and where uniform and heavy infestations were the rule rather than the exception.

Method of Determining Effectiveness of Parasite Releases

The tentative plans for obtaining data on results of the liberations of *Trichogramma minutum* were discarded. Early in the season dependable data could not be obtained from the few eggs that could be found, and later in the season dry weather and shuckworm infestations caused dropping of nuts in midseason. Also, even when the drops

were carefully picked up and when weeds and grass under the trees were kept down, too many of the small nuts were washed away during the summer rains.

A rather satisfactory method of obtaining results was based on the fact that after the nut casebearer larva tunnels into one of the nuts in a cluster, this nut ceases to grow and later drops off. For a time, however, it is prevented from falling by the conspicuous webbing (fig. 3) that the larva spins in going to the next small nut of the cluster. Since it is unusual for a single cluster to have more than one

Figure 3.—Infested cluster of pecans showing dark mass of frass and webbing tube preventing small nut at upper left from falling.

larva, an infested cluster represented one egg that had escaped parasitization. Comparison of percentages of infested clusters from the two plots of each experiment is, accordingly, a good measure of the effects of the parasite releases on infestation.

It was found that by using six-power prism binocular field glasses, infested and noninfested clusters, even in the tops of the trees, could be counted from the ground accurately and quickly. This method of counting eliminated the use of ladders and speeded up the work. Since many more clusters could be examined in the time available, the data became more dependable.

Releases of *Trichogramma minutum*

Nineteen experiments were conducted on the use of *Trichogramma minutum* for control of the pecan nut casebearer. The experiments were spread out over a 5-year period, and were located in six pecan-growing localities—five in Georgia and one in Florida. One experiment in Georgia was terminated because of a low infestation level. Liberations of parasites were timed very carefully to coincide with the spring oviposition period of the host insect, beginning with the first signs of egg-laying or larval infestation. These initial dates varied slightly during the five seasons—May 18 in 1931, and May 10, 2, 11, and 17 in succeeding years. Data on releases of parasites, and the comparative infestations by the nut casebearers resulting in the various plots are summarized in table 2. In no case did the releases miss the oviposition period of the nut casebearer, but in some of the earlier experiments more parasites could have been used if they had been available.

Results of Control Experiments

The natural infestations of nut clusters attacked by nut casebearer larvae ranged from 0 to 10 percent in all except 1 of the 12 Georgia experiments and from 10 to 25 percent in the 6 Florida experiments. Although no certain way of forecasting heavy infestations was found, the infestations in the experiments were decidedly heavier than the general average for the years in question.

Where from 20,000 to 125,000 parasites of the dark strain (L) of *Trichogramma* were used per tree, and where only 2,500 to 10,000 parasites of the yellow strain (T) were used per tree, there were no significant reductions in infestation. Where the parasites released were 11,000 or 12,000 of the yellow strain (C) per tree, there was indication of reduction in 1 experiment, but the percentages of infestation were so low that the results cannot be considered statistically reliable. In experiment 7, in which 54,500 dark (L) and 40,000 yellow (A) *Trichogramma* parasites were liberated per tree, there was a definite reduction in infestation in the colonized trees. Where parasites of the yellow strain (C) were used at the rate of 200,000 per tree, rather definite reductions in nut casebearer infestation occurred in the colonized plots. Statistical analysis of variances strengthened the conclusion that the differences were due to releasements.

Looked at from the standpoint of a commercial grower, however, the degree of control could hardly be called economical. For example, if the trees held a potential crop of 60 pounds of nuts and these would bring 20 cents per pound, the gross return for each tree would be $12. If 30 percent of the clusters were infested, the maximum possible damage per tree would be $3.60, and since an infested cluster usually has enough nuts to satisfy the larva and then mature one or two nuts unhurt, the true damage would certainly be much less. At $6.51 per million, the lowest cost of production in the experimental laboratory (*6*), 200,000 *Trichogramma* parasites per tree would cost $1.30,

837634—49——2

TABLE 2.—*Experimental liberations of Trichogramma minutum for control of the pecan nut casebearer*

Year and location	Pecan variety	Trees	*Trichogramma minutum* releases			Pecan nut clusters		
			Strain	Dates	Total parasites per tree	Examined in each plot	Infested by nut casebearer larvae [1]	
							Colonized plot	Check plot
		Number			*Number*	*Number*	*Percent* [2]	*Percent*
1931								
Baconton, Ga	Schley	60	T	May 14 and 22; June 5	10, 000	500	1. 0±0. 6	0. 2±0. 3
Putney, Ga	Mixed	118	T	May 18, June 3	7, 500	500	1. 0±0. 8	0
Albany, Ga	Schley	38	T	May 18, June 1	5, 000	500	7. 4±1. 0	5. 4±1. 2
Baconton, Ga	Pabst	60	T	May 20, June 5	7, 500	500	. 8± . 5	1. 4± . 6
Do	Mixed	101	T	May 22	2, 500	500	0	0
Philema, Ga	do	135	T	May 27	2, 500	500	0	0
1932								
Monticello, Fla	Moore	10	A	May 10 and 21	40, 000	2, 247	9. 8± . 9	17. 2±1. 2
			L	May 27 and June 3	54, 500			
Albany, Ga	Pabst	15	L	May 24, June 6	20, 000	4, 324	24. 2±2. 0	[3] 29. 1±2. 4
1933								
Monticello, Fla	Moore	10	L	May 2, 8, 13, 18, and 23	125, 000	2, 304	22. 3±1. 9	25. 3±1. 3
Do	do	25	L	May 2, 8, 13, 18, and 23	125, 000	5, 203	14. 1± . 7	14. 4± . 9
Do	Mahan	40	L	May 4, 11, 16, 20, and 28	25, 000	1, 894	16. 3±1. 6	11. 4±1. 3
Albany, Ga	Schley	30	L	May 3, 10, 15, 19, and 25	125, 000	4, 413	4. 2± . 6	5. 8± . 7
1934								
Dawson, Ga	Pabst	20	C	May 17, 19, 22, June 4	11, 000	3, 969	1. 0± . 2	1. 7± . 3
Albany, Ga	Schley	20	C	May 22 and 25, June 5	12, 000	3, 129	5. 3± . 8	5. 6± . 6

1935								
Dawson, Ga	do	24	C	May 11, 16, 21, and 25	200, 000	4, 800	3. 0± . 7	8. 9±2. 0
Albany, Ga	do	20	C	May 11, 15, 21, and 27	200, 000	4, 000	1. 4± . 5	2. 6± . 8
Monticello, Fla	Moore	20	C	May 13, 17, 23, and 28	200, 000	4, 000	3. 0± . 7	11. 3±2. 7
Do	Mahan	20	C	May 13, 17, 23, and 28	200, 000	4, 000	6. 4±1. 6	16. 3±3. 9

[1] Approximately the same numbers of clusters were examined in the colonized and the uncolonized check plots.

[2] Standard error of mean.

[3] Total of: NE 9 trees—2,164 clusters examined, 21 percent infested; SE 6 trees—561 clusters examined, 34.7 percent infested; W 10 trees—1,719 clusters examined, 37.4 percent infested.

labor cost of release would have to be added, and only a partial reduction of infestation and damage could be obtained. A 25- or 30-percent infestation was encountered only twice in the experiments in spite of earnest efforts to find heavy infestations for the work. The best control obtained was only partial, and there is no sure way to forecast infestations. A grower would have to buy these large numbers of parasites each year for each tree, knowing full well that the probability of a damaging infestation is remote.

Undoubtedly there will be growers who think that these infestation records are much too low, and that sometimes nut casebearers "take the whole crop." It must be remembered, however, that there are other causes than nut casebearer infestation responsible for the dropping of nuts. Some of these causes are very dry weather, heavy winds, diseases such as scab, soil fertility too low to mature and fill out a heavy nut crop, and work of other insects, including stinkbugs and shuckworms. A nut injured by a nut casebearer larva is hollowed out or has a hole in it, and almost always remnants of the blackish, silky web may be found. Dropped nuts without these plainly visible signs should not be blamed on the nut casebearer.

The sporadic character of nut casebearer infestations, especially in Georgia, suggest that it would be more profitable for the growers to accept the small losses once in 3, 4, or 5 years than to invest even moderate amounts for partial control by parasites each season.

THE PECAN LEAF CASEBEARER

Seasonal History and Habits

A complete description of the pecan leaf casebearer, including life history, seasonal history, habits, and control measures, has been given by Gill (*2, 3*). Therefore, only those matters that have a bearing on these experiments need be discussed.

The small larvae of the leaf casebearer live through the winter on the buds in scalelike shells called hibernacula. When the buds swell and growth starts, these larvae become active and feed on this tender growth, and, when numerous, may prevent the setting of a crop of nuts by devouring the leaves and flower buds as fast as they grow out. The larvae pupate between April 15 and June 20, and 16 to 23 days after pupation the adult moths emerge and begin to lay eggs. Because of the extended pupation period, emergence of adult moths is also stretched out over several months; therefore there is a long oviposition period. The eggs, almost without exception, are laid on the under surfaces of the leaflets, along the midribs. Usually they are pushed down into the angles formed by the midrib and side veins. Such large numbers are laid during the summer and early in the fall that, in uncontrolled outbreaks, uninfested leaves are rare.

The eggs are attacked by several other natural enemies in addition to *Trichogramma minutum*. The eggs hatch in 6 to 9 days, and the larvae feed during the remainder of the summer in conspicuous serpentine mines along the midribs of the leaflets. They grow very little during this time. Just before the leaves begin to turn yellow and fall, the larvae migrate to the buds and spin their flat, brownish hib-

ernacula. This habit of the small larva is interesting, because otherwise the leaves would carry them to the ground and in the spring they would not be in such favorable positions to reach the new growth, their preferred food. The damage done by the larvae during summer and fall is not important, but the fact that they eat the leaves gives opportunity for control by insecticides. It was thought that small releases of *Trichogramma* early in the period of oviposition would provide a parasite nucleus that would breed up to vast numbers by fall, destroy many eggs in so doing, and reduce the number of larvae that would enter hibernation. Therefore each summer, when parasites became available after the nut casebearer experiments were finished, experiments were run on other plots for control of the leaf casebearer.

Releases of *Trichogramma minutum*

Six grove experiments were conducted on control of the leaf casebearer, one at Putney, Ga., in 1931 and the others at Albany, Ga. The numbers of *Trichogramma* parasites released ranged from 120 to 300,000 but 4 of the experiments received liberations exceeding 120,000 parasites per tree.

Experimental Control Technique

The plots were easy to select, and there was no uncertainty about obtaining infestations. At first buds on twigs were examined with binocular microscopes for hibernacula, and when many were found in the samples the location was considered suitable. Later on selection of plots was deferred until damage to terminals and blooms could be seen. Heavy terminal feeding by larvae indicated favorable sites for experiment, and there was time during the period of pupation to make all necessary arrangements. The plots were paired as in work already discussed, but were farther apart because of the greater opportunity the parasites had for spreading during the longer oviposition period. The parasites were released just as in the nut casebearer work.

The method of counting winter hibernacula to determine results was never used because so many extraneous factors affect the insects between the egg-laying time and winter. In 1931 the percentages of parasitization in eggs from the colonized plots were compared with those in the uncolonized check plots. After that year the serpentine, summer feeding areas of the young larvae, counted just before the leaves fell, were used instead. If parasitic control had been accomplished by releases of *Trichogramma* in the colonized plots, the number of serpentine mines should be less than where no parasites were used. This method of ascertaining results was found to be satisfactory.

Results of Control Experiments

In 1931 5,000 parasites were released in 96 trees, and examination of 352 casebearer eggs showed a parasitization of 11.7 ± 4.2 percent as compared with 13.5 ± 3.8 percent in 393 eggs from an equal number of check trees. The results of the other experiments are summarized

in table 3. A partial reduction in infestation was obtained in three of the six experiments and negative or contradictory results in the other three. In no case was the apparent control sufficient to be satisfactory to the commercial grower nor were the results comparable with those possible from the use of suitable insecticides. Two larvae left alive for each leaf would be too many, and 7 to 10 living larvae would result in heavy damage the following year.

TABLE 3.—*Experimental liberations of Trichogramma minutum for control of the pecan leaf casebearer*

Year of experiment	Pecan trees	*Trichogramma minutum* releases			Leaves examined [1]	Spiral cases of leaf casebearer larvae per leaf	
		Strain	Dates	Total per tree		Colonized plot	Check plot
	Number			*Number*	*Number*	*Number*	*Number*
1932	16	L, Z	June 10, 15, 20, and 24.	121, 900	139	7. 5±0. 6	5. 9±0. 7
1933	20	L	June 13, 20, and 26, July 3, and 14.	125, 000	400	7. 4± . 4	11. 0± . 7
1934	20	C	June 21	120	200	10. 0± . 6	14. 8± . 8
1935	20	C	June 4, 10, 17, and 24, July 1, and 8	300, 000	4, 000	1. 9± . 1	3. 1± . 2
1935	20	C	June 8, 15, 22, and 29, July 6, and 13	300, 000	4, 000	2. 4± . 2	2. 0± . 1

[1] An equal number of leaves from an equal number of trees were examined in the uncolonized check plot.

THE HICKORY SHUCKWORM

SEASONAL HISTORY AND HABITS

The hickory shuckworm, originally an enemy of the scattered native hickories, has found conditions in pecan groves suitable for reproduction, but its seasonal cycle is not too well synchronized with that of the pecan, which is very slow in budding out and blooming in the spring (*5*). Adult shuckworms emerge from pupae in hickory and pecan shucks from the middle of March to the last of April, with the peak emergence about April 1. On hickory trees the females oviposit on the small nuts, but the pecan trees have not bloomed and no small nuts are available, so the eggs are laid on the leaves. These eggs hatch in a few days and nearly all the larvae perish from lack of their usual food—the shucks of young nuts. So each year the shuckworm has a severe set-back on pecan, because of this lack of synchronization.

From a few late-emerging females and from females which have developed in nearby hickories, or which manage to survive in spite of adversity on pecans, an infestation develops on this host plant by midseason, and by picking time in the fall the infestation may be heavy.

Shuckworm eggs may be found through the growing season to picking time, but their abundance varies greatly, according to the numbers of females ready for oviposition and also according to the weather, as the temperatures and humidities must be within certain limits or the females will not lay eggs. There are several irregularly spaced oviposition peaks during the season (*7*). Because of its long egg-laying season the hickory shuckworm seemed to be a particularly favorable host for control by *Trichogramma* parasites. Not only could control be exerted by the numbers of parasites released, but also by the succeeding generations of the parasites produced through the months when the host eggs were plentiful.

Releases of *Trichogramma minutum*

Two grove experiments were conducted on control of the hickory shuckworm with *Trichogramma* in 1931, a single experiment followed each year in 1932 and 1933, and in 1935 a pair of experiments was completed. The first experiment was conducted near Baconton, Ga., the second near Thomasville, Ga., and the other four east of Albany, Ga. The pecan varieties used were Stuart and Schley in 1931, Schley in 1932, and Moore for the last three experiments. Details of the strains of *T. minutum* and the numbers of parasites used in each experiment are included in table 4.

Table 4.—*Experimental liberations of Trichogramma minutum for control of the hickory shuckworm*

Year of experiment	Pecan trees	*Trichogramma minutum* releases			Infestation by shuckworm larvae			
		Strain	Dates	Total parasites per tree	Drops		Harvested nuts	
					Colonized plots	Check plots [1]	Colonized plots	Check plots [1]
	Number			*Number*	*Percent*	*Percent*	*Percent*	*Percent*
1931	16	T	July 28 and 31, Aug. 2, 7, 10, 14, 17, and 21.	50,000	3.3	2.5	25.5	22.3
1931	9	T	Aug. 4, 11, 18, and 25, Sept. 1 and 8.	40,000	15.2	13.3	41.0	31.0
1932	10	L, Z	July 11	10,000	5.1	3.7		
1933	20	L	July 26, Aug. 3, 12, and 22, Sept. 1 and 11.	156,250	12.2	12.9	.5	.5
1935	20	C	July 20 and 27, Aug. 3, 9, 16, and 24.	250,000	25.6	32.2	22.9	19.8
1935	20	C	July 20 and 27, Aug. 3, 9, 16, and 24.	250,000	20.9	22.2	17.7	21.7

[1] The check plots in each experiment consisted of the same number of trees as were in the colonized plot.

Experimental Control Technique

In the shuckworm experiments the blocks were arranged as they were in the nut casebearer and leaf casebearer experiments, and the parasites were released similarly. In addition to the method of obtaining percentages of parasitization in shuckworm eggs, which was abandoned because of difficulty encountered in locating eggs, two other methods of estimating possible benefits from the colonizations were available. One was by comparison of the small nuts dropped by larval infestations on check and colonized plots. Then, toward harvest-time, it was possible to obtain samples of nearly matured nuts with shucks intact, and by cutting the shucks with knives, the numbers of larvae could be ascertained for uncolonized and colonized trees. Both these methods were used in the experiments.

Results of Control Experiments

In the first four experiments (table 4) no reductions in percentages of infested drops were obtained by the releases, nor was there any reduction in infestation in nut samples at harvesttime. In the first experiment in 1935 there was an apparent reduction of 6.6 percent in infested drops, but the reality of this reduction must be questioned because at harvest the infestation was higher by 3.1 percent in nut samples from the trees that received parasites than from the check trees. In the second experiment in 1935 infested drops were 1.3 percent fewer under colonized trees, and at harvest the infestation was 4 percent less in samples of nuts from trees that had received *Trichogramma* parasites.

Even if these reductions had been consistent and uniformly obtained in the six parasite plots, the actual economic benefits would have been small and would have reimbursed the grower for only a small part of the cost of the parasites and their releases. Where the total drop is less than 5 percent of the crop set and only one-tenth to one-fourth of the drops are infested, a reduction of 7 percent in infested drops means almost nothing to the grower. And a reduction of 4 percent in infestation of nuts at harvest—the single case of apparent benefit in six experiments—is likewise neither convincing nor of especial value to the grower.

SUMMARY AND CONCLUSIONS

Between 1931 and 1936 more than 30,000,000 parasites of the species *Trichogramma minutum* Riley were reared and released in 19 experiments on control of the pecan nut casebearer (*Acrobasis caryae* Grote) in Georgia and Florida pecan groves. Numbers released ranged from 2,500 per tree in the earlier experiments to 200,000 per tree in 1935. Both yellow and dark varieties of the parasite were used.

Although efforts were made to obtain groves with heavy host populations, natural larval infestations exceeded 25 percent of the nut clusters in only two of the groves, and in all but four cases were less than 15 percent. Where the dark strain of *Trichogramma* was used, even in such large numbers as 125,000 per tree, no reduction in nut-cluster infestations occurred. Where the yellow strain of *Trichogramma* was released at the rate of 40,000 parasites per tree together with 54,000 of the dark strain, and where the yellow strain alone was released at the rate of 200,000 per tree, statistically significant reductions in infesta-

tion were obtained. The highest percentage of nut clusters attacked in any of the experiments, 29.1, was greater than the percentage of actual damage to crop yield, since seldom are all the nuts destroyed in the infested clusters. Therefore, in the highest of these infestations, the percentage of the crop saved by releases of large numbers of parasites was probably much lower. In view of the sporadic incidence of the nut casebearer attacks from year to year, the impossibility of predicting heavy infestations, the cost of producing and distributing large numbers of the parasites, and the small benefits demonstrated, the method of controlling the nut casebearer by release of *Trichogramma* appears to be impractical.

Nearly 17,000,000 additional *Trichogramma* parasites, both dark and yellow strains, were used in experiments on control of the pecan leaf casebearer (*Acrobasis juglandis* (LeB.)). There were six grove experiments, all near Albany, Ga. Releases ranged from 120 to 300,000 per tree, but exceeded 120,000 in 4 experiments. Real damage and heavy infestations by the leaf casebearer were encountered in each experiment. In three of the cases benefits from releases were negative. In three experiments positive reductions were shown, but the actual control was insufficient.

Six experiments on control of the hickory shuckworm (*Laspeyresia caryana* (Fitch)) involved the use of over 14,000,000 additional *Trichogramma* parasites in pecan groves. The numbers of parasites released per tree ranged from 10,000 to 250,000. No significant reduction in shuckworm infestation in the drops resulted except in one experiment in which 250,000 yellow *Trichogramma* parasites per tree were used and in this instance the reduction was only 6.6 percent. Examination of samples of nuts at harvest revealed higher larval infestations where parasites had been released in four of the experiments and a 4-percent lower infestation than in the check in just one instance.

These results indicate that releases of *Trichogramma minutum* would not be satisfactory as a method of control for infestations of insects in pecan groves.

LITERATURE CITED

(1) FLANDERS, S. E.
1930. MASS PRODUCTION OF EGG PARASITES OF THE GENUS TRICHOGRAMMA. Hilgardia 4: 465–501, illus.

(2) GILL, J. B.
1917. THE PECAN LEAF CASEBEARER. U. S. Dept. Agr. Bul. 571, 28 pp., illus.

(3) ———
1924. IMPORTANT PECAN INSECTS AND THEIR CONTROL. U. S. Dept. Agr. Farmers' Bul. 1364, 49 pp., illus.

(4) HINDS, W. E., and SPENCER, H.
1928. UTILIZATION OF TRICHOGRAMMA MINUTUM FOR CONTROL OF THE SUGARCANE BORER. Jour. Econ. Ent. 21: 273–278, illus.

(5) MOZNETTE, G. F., BISSELL, T. L., and ADAIR, H. S.
1931. INSECTS OF THE PECAN AND HOW TO COMBAT THEM. U. S. Dept. Agr. Farmers' Bul. 1654, 60 pp., illus.

(6) SPENCER, H., BROWN, L., and PHILLIPS, A. M.
1935. NEW EQUIPMENT FOR OBTAINING HOST MATERIAL FOR THE MASS PRODUCTION OF TRICHOGRAMMA MINUTUM, AN EGG PARASITE OF VARIOUS INSECT PESTS. U. S. Dept. Agr. Cir. 376, 18 pp., illus.

(7) WALKER, F. W.
1933. THE PECAN SHUCKWORM. Fla. Agr. Expt. Sta. Bul. 258, 18 pp., illus.

U. S. GOVERNMENT PRINTING OFFICE: 1949

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents